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Sector Energy Price and Demand in the State of Florida

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SECTOR ENERGY PRICE AND DEMAND

IN THE STATE OF FLORIDA: 1978-1994

BY

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INTRODUCTION

There are available today an abundant number of energy models for predicting both the price and consumption of energy. Many of these project energy price and consumption trends on a nation wide basis. Such a model is the PIR model (Project Independence Report). This model was developed by the Federal Energy Administration and attempts to project energy supply and demand based on macroeconomic growth (Hausman 1975, p. 518). Other models, such as the model developed by MacAvoy - Pindyck, are much more limited in scope and as in this case, deal with one fuel type (MacAvoy - Prindyck model deals with natural gas) (MacAvoy and Pindyck 1975).

All of these models, whether they are very simplistic in nature, or of a very sophisticated design, are subject to one major flaw. That is, that whenever one of the variables change, previous predictions are at that point, invalid. Any price or consumption projections made before 1973, or between 1973 and 1979, missed the Arab oil embargo and the Iranian crisis respectively. These events changed the basis on which the previous projections were made. The changing variables not only affect the projections made by the model but also makes other studies that were done, which were based on information provided by those models, invalid.

An attempt will be made to forecast future energy price and consumption trends in the State of Florida, and to calculate payback periods for residential solar space and water heating systems. A regional energy model developed by J. R. McNamara at Lehigh University is used to accomplish this. Two scenarios are simulated in an effort to establish worst, expected and best case information at differing rates of demand growth. The purpose of the two scenario/three case design is to allow for changes in the energy market and the effects those changes will have on future consumption and prices.

After future energy prices and consumption trends have been established, they will be compared to the price of solar space and water heating systems for the residential sector. A year by year calculation is made to determine the amount of time required to recover the initial investment in the solar system.

Solar technology has not experienced wide usage in the recent past. This has been due to the availability of relatively cheap supplies of fossil fuels and the high initial cost of purchasing solar equipment. As long as the price of fossil fuels remained low, the payback periods on the initial investments for solar equipment have been long in duration. With the cost of fossil fuels rising, this situation is beginning to change.

Centrally generated electricity, for example, becomes more expensive per kilowatt hours (KWhrs.) as the cost of fossil fuels rise. The effect is to shorten the payback period for the initial investment in solar equipment. The same observation can be made with respect to heating oil. Solar heating for home and industrial uses has always been a substitute for oil. Oil has been used because of its low cost. However, as the cost of oil continues to increase, the comparative cost of using solar decreases. An obvious outcome would be that for various applications, solar will be cheaper to use than oil. The same case can be made for natural gas and coal. It should be noted that the dollar value of the energy used, per unit, will be cheaper for solar produced energy than oil, but does not reflect any of the social or personal costs associated with solar technology.

All values, both for energy prices and for solar energy equipment, are calculated in constant dollar values (1967 = 100). The reason for this is to calculate the real payback period. That is, to calculate the time required for the individual to recover the purchasing power of the dollars initially spent on the solar system (by calculating the real payback period, any effects of inflation on the dollar is eliminated).

The paper begins with a description of the model used and then describes the process by which the variables required for the model were obtained and/or calculated. The results of the model are then presented and finally, conventional and solar heating systems costs are presented and payback periods are established. The appendix contains original price and consumption data for reference.

CHAPTER I

THE MODEL

The model serves to project future energy prices and consumption patterns. In its present form, it is based on a system of 24 linear functions solved simultaneously: four functions describing the energy demand for each sector, four functions describing the conversion of primary fuels into final energy forms and 16 functions describing the supply of the four types of fuel to each sector. The model can be expanded to include eight fuels for two regions of four consuming sectors each producing a system of 80 linear functions (McNamara and Martin 1979). After each year, all the equations are updated with the newly generated data.

In this simulation, four primary fuels are considered: petroleum, natural gas, nuclear and coal. With the exception of gasoline (the transportation sector is not included), these are the fuels used as primary energy in Florida. Four consuming sectors are identified; residential, commercial, industrial and electric. Electric use is not segregated by final consumption. The fuel consumed by the electric sector represents fuel use by electric utilities. This is the same for the other sectors as well. The final energy price in the electric sector represents the price of electricity to the other three sectors. Final energy prices for residential, commercial and industrial sectors represents the price paid for the fuels, other than electric, consumed by that sector. The program excludes the use of nuclear fuel for purposes other than electrical generation.

The model requires nine sets of input data. The first set of data is the control parameters. This set consists of the number of regions, consuming sectors, the number of fuels, the inflation rate, demand lag, the year in which the projection ends and the print skip pattern (the years for which data is printed). The demand lag is the rate at which supply lags desired consumption. The most important or influential variable in this data set is the inflation rate. This variable represents an average annual inflation rate for energy prices and of the remaining variables has the greatest effect on the long run increase in energy prices. Six different inflation rates are used in establishing the worst, best and expected projections.

Another data set that is important in the long-run is the demand growth rate. This variable is an average annual growth rate in the demand for energy for each sector. Two estimates for demand growth are used and are more fully discussed in the variable section along with the other data sets; supply elasticities, demand elasticities, growth constraints, depletion rates (long-run marginal costs of each fuel), fuel consumption, the marginal productivities of each fuel in each sector, non-fuel costs and final energy prices.

Short-run adjustments in the model are made by manipulating the marginal productivities, non-fuel costs, and final energy prices. Due to the manner in which these values are calculated, it is very important that they be in balance with one another. If they are not balanced, the model will not calculate the correct final energy prices for each sector in the base year. Since the correct prices are known in advance, this serves as a validation of the marginal productivity and non-fuel cost calculations.

Cross-price elasticities of demand are not included in the model. This would illustrate the response in the demand of one fuel when the price of another fuel changed (would generally assume some fuels are substitutes for each other). In the model's present form, substitution of one fuel for another is based on price and marginal productivity. Fuel usage will generally shift to the fuel with the highest efficiency (marginal productivity) or the lowest price, or a combination of both (generally the marginal productivity is more important). Shifting to a more expensive fuel with a high marginal productivity could be less expensive than using a cheaper fuel with a low marginal productivity. This relationship is reflected in the model's results (industrial use of coal).

Finally, variables that would have a significant influence on fuel supply or consumption, like the irregular appearance of new inventions or world events such as the Iranian crisis, can not be foreseen by the model. However, the model is relatively inexpensive to use and by changing the input data many scenarios can be simulated. Projected consumption and price data should not be viewed as absolute values, but as projected estimates that describe long-run trends.

CHAPTER II

Chapter II describes the variables, lists the values for each, and the methods used to derive the values. The variables are considered in the following order; fuel consumption, final energy prices, marginal productivities, non-fuel costs, supply elasticities, demand elasticities, demand growth, capacity growth, and the reserve depletion rates.

FUEL CONSUMPTION

TABLE 1

1978 FUEL CONSUMPTION IN TRILLIONS OF BTUS

Sector	Fuel 10^{12} BTUs				Electric**
	Petroleum*	Natural Gas*	Nuclear*	Coal*	
Residential	22.2	22.4	N/A	N/A	130.86
Commercial	41.9	28.3	N/A	N/A	83.06
Industrial	110.4	77.5	N/A	7.0	47.17
Electric	483.3	160.8	169.9	163.8	-

*SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

**SOURCE: Thompson, Ralph B., ed., Florida Statistical Abstract (Gainesville, Florida: The University Presses of Florida, 1979), Table 15.91, p. 359.

Fuel consumption is simply the quantity of each fuel consumed by each sector in 1978, measured in trillions of BTUs. A British Thermal Unit, BTU, is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2^{o}F (Woolf 1974). Natural gas, coal and nuclear fuel are singular in nature while petroleum may be subdivided into several categories: liquified petroleum gas, distillate fuel oil (kerosene, diesel and others) and residual fuel oils. These categories are combined for use in the model (data made available through the State Energy Department). Fuel consumption values are listed in Table 1.

TABLE 2

ELECTRICAL CONSUMPTION BY SECTOR: 1978

(ROUNDED TO MILLIONS OF KWhrs.)

Sector	Year	
	1969	1978
Residential	19,375 KWhr.	38,353 KWhr.
Commercial	10,895 KWhr.	24,345 KWhr.
Industrial	8,495 KWhr.	13,824 KWhr.

SOURCE: Thompson, Ralph B., ed., Florida Statistical Abstract (Gainesville, Florida: The University Presses of Florida, 1979), Table 15.91, p. 359.

In order to determine the BTU value of the electric consumption for each sector as listed in Table 2, a conversion factor of

$$1 \text{ KWhr.} = 3{,}412 \text{ BTUs}$$

was used. The KWhr. consumption data was obtained from the Florida Statistical Abstract 1979.

FINAL ENERGY PRICES

TABLE 3

1978 FINAL SECTOR ENERGY PRICES; $\$/10^6$ BTU

Sector	$\$/10^6$ BTU	
Residential	2.14	
Commercial	1.72	In Constant $'s
Industrial	1.00	
Electrical	6.22	

Final sector energy prices, the price paid for fuels delivered for use to each sector, are arrived at through a series of weighted price averages of the various fuels consumed by each sector and are listed in Table 3. The weighted average takes the form of:

$$\sum_{i=1}^{n} (\text{Price})(\%\ \text{Weight})$$

A weighted process is used because a simple averaging of the prices paid for the various fuel types consumed does not accurately reflect the true price paid for energy by a particular sector. By weighting the price paid for each fuel by the percentage of the total energy, consumed in the sector, the fuel makes up (in terms of BTUs), a more accurate average price paid is derived. An example may serve to better illustrate this process.

In the residential sector in 1978, two fuel types were consumed: petroleum and natural gas. Petroleum can be broken down into liquified petroleum gas and distillate fuel oils (kerosene and other). A total of 22.2 trillion BTUs of petroleum was consumed. Of that, 15 trillion or 68% was liquified petroleum gas, 3.1 trillion or 15% was kerosene, and 4.1 trillion or 17% was other distillate fuels. The residential sector paid 243.6¢/10^6 BTUs for liquified petroleum gas, 207.1¢/10^6 BTUs for kerosene, and 174.7¢/10^6 BTUs for other distillate fuels. It is now possible to develop a weighted price average for petroleum for the residential sector based on fuel price and percentage of fuel consumed. Calculation:

$$\begin{pmatrix}\text{Price of Liquified}\\ \text{Petroleum Gas}\end{pmatrix}(\%\ \text{Use}) + \begin{pmatrix}\text{Price of}\\ \text{Kerosene}\end{pmatrix}(\%\ \text{Use}) + \begin{pmatrix}\text{Price of}\\ \text{Other}\end{pmatrix}(\%\ \text{Use}) =$$

$$(243.6¢/10^6\ \text{BTU})\quad(.68) + \begin{pmatrix}207.1¢/\\ 10^6\ \text{BTU}\end{pmatrix}\quad(.15) + \begin{pmatrix}174.7¢/\\ 10^6\ \text{BTU}\end{pmatrix}\quad(.17) =$$

Final Weighted Price for Petroleum = <u>223.2¢/10^6 BTU OR 2.23\$/10^6 BTU</u>

In 1978, residential use of energy amounted to a total of 44.6 trillion BTUs. Approximately 50% of that (22.2) was petroleum.

Natural gas consumption made up the other 50% (22.4). Natural gas cost the residential user 203.8¢/10^6 BTUs. Using the weighted price average derived for petroleum, it is now possible to derive a final weighted price average for energy in the residential sector.

(Price of Petroleum) (% Use) + (Price of Natural Gas) (% Use) =

(223.2¢/10^6 BTUs) (.5) + (203.8¢/10^6 BTUs) (.5) =

Final Weighted Price for Petroleum = <u>213.5¢/10^6 BTUs</u>

OR = <u>2.14$/$10^6$ BTUs</u>

This final weighted price average is then used in the model as the final sector energy price for the residential sector. This process is repeated for each sector with the exception of the electric utility sector (Thompson 1979, p. 359). Because electricity is not broken down by final use, the dollar value in the electric sector represents a weighted price average paid for electricity by the residential, commercial and industrial sectors (Florida Department of Energy 1980). All price data are constant dollar values.

MARGINAL PRODUCTIVITY

The marginal productivity of a fuel reflects the efficiency of that fuel in the sector in which it is used. For the residential, commercial and industrial sectors, the marginal productivity of each fuel is a function of the cost of the fuel, final energy prices, and non-fuel costs (McNamara and Martin 1979). It is calculated in the following manner:

$$MP = \frac{C}{(F - N)}$$

C = Cost of Fuel

F = Final Energy Price for Energy in a Sector

N = Non-fuel Costs for a Fuel in a Sector

The cost of petroleum and natural gas is not identical for each sector. A residential user pays a much higher price for both fuels than does an industrial user (this is very similar to the problem faced when trying to determine some average price for energy in each sector). In order to establish some single price for petroleum and natural gas, a weighted price average is used, in the form of:

$$\sum_{i=1}^{n} (\text{Price})(\text{Weight})$$

n = Number of Fuels

TABLE 4

PERCENTAGE FUEL USE BY SECTOR

Sector	Fuel			
	Petroleum	Natural Gas	Nuclear	Coal
Residential	3%	7%	Ø	Ø
Commercial	6%	10%	Ø	Ø
Industrial	17%	27%	Ø	4%
Electric	74%	56%	100%	96%

Using the amount of a type of fuel consumed in each sector and the total amount of the fuel consumed in the State, the percentage of the fuel consumed by each sector is determined. These percentages are given in Table 4. The percentages are then multiplied by the price paid for the fuel by each sector and then summed. The result is a weighted price average of the cost of a fuel. Having found the cost of fuel, it is now a simple matter of substitution in order to find the marginal productivity values for the residential, commercial and industrial sectors.

In the case of electrical production, non-fuel costs have not been established. However, the marginal productivities of the various generating methods (dependent on fuel used) are known. By rearranging the formula to

$$N = F - \frac{C}{MP}$$

it is possible to generate the non-fuel costs needed.

At first glance, it may seem that the engineering marginal productivities for electrical production are relatively low with respect to the other sector's marginal productivities. While they are lower, it is not without reason. Fuel used in the residential sector is processed through one stage while fuel used to generate electricity is processed through two stages. For example: in the home, natural gas is burned in a water heater which uses the heat released to directly heat water; one step or transformation. In an electrical plant using natural gas for fuel, the heat released when the natural gas is burned is used to change water into high pressure steam; one step. The steam is then used to drive a turbine to which the generator is attached; second step. Because the energy is transformed a second time from steam to mechanical energy, more energy is lost through heat loss. This two step process accounts for the lower marginal productivity involved in the use of a fuel for the production of electricity (this applies for the other fuels and sectors also).

The non-fuel costs generated for electrical production are considerably higher than in the other sectors. This might have been expected given the high capital costs involved in transforming primary fuel to electricity and then the transmission of that electricity to the final user.

NON-FUEL COSTS

TABLE 5

NON-FUEL COSTS IN $\$/10^6$ BTU

Sector	Fuel			
	Petroleum	Natural Gas	Nuclear	Coal
Residential	.56	1.35	N/A	N/A
Commercial	.16	.54	N/A	N/A
Industrial	.01	.24	N/A	.08
Electric	2.99	4.40	5.92	4.80

Non-fuel costs reflect the percentage of the price of each fuel for each sector that is not part of the actual costs paid for the fuel. Non-fuel costs would include, but are not limited to, transportation and wholesalers profit. In the case of electricity, most of the cost is non-fuel. These non-fuel costs would reflect the costs of actually delivering centrally generated electricity to the users location and would include transmission lines, poles, transformers, switchgear, and the maintanence of that equipment. National average prices are used in deriving these costs for the residential, commercial, and industrial sectors (U.S. Department of Energy 1979).

In order to calculate the percentage of fuel costs that are non-fuel costs, the percentage difference between the wholesale price and retail price is derived for a sector for each fuel (in the case of natural gas, average well head price is used) consumed in that sector. The price for each fuel in a sector is then multiplied by this percentage. The resultant product yields the non-fuel costs for each fuel for a sector. In the case of coal for industrial use, a value of ten percent is assumed which is generally consistent with the other non-fuel costs for that sector. Non-fuel costs for electricity are determined using marginal productivities.

SUPPLY ELASTICITIES

Elasticity of supply can be defined as the percentage increase in the quantity supplied given a 1% increase in price, or

$$E_s = \frac{dQ_s}{dP} \times \frac{P}{Q_s} = \frac{\%\Delta Q_s}{\%\Delta P}$$

TABLE 6

SUPPLY ELASTICITIES

Sector	Fuel			
	Petroleum	Natural Gas	Nuclear	Coal
Supply Elasticities	.5	.5	.4	.6

The elasticity of supply is an indicator of the responsiveness of the supplier of a fuel to a change in the price of the fuel. If E_s is greater than one, the percentage increase in the quantity of fuel supplied is greater than the percentage increase in the price of fuel. This would indicate that the fuel supplier is relatively responsive to an increase in the price of the fuel. Supply would then be said to be relatively elastic. If a one percent increase in fuel price brings about an one percent increase in the quantity of fuel supplied, supply is then said to be unit elastic. If E_s is less than one, then the percentage increase in the quantity supplied is less than the percentage increase in price. Under these conditions, supply is said to be relatively inelastic indicating that fuel supply was not very responsive to price changes.

The model requires estimates of short-run elasticities of supply (the short-run being defined as one year or less and the long-run being more than one year). Because of the time lag involved in the development of new fuel supplies (exploration, site development, etc.), supply is relatively inelastic in the short-run (Jenkins 1977). The elasticities used in the model, listed in Table 6, are somewhat greater than elasticities based strictly on estimated fuel reserved at various prices (lower in the case of nuclear). In the case of natural gas and petroleum, this is to allow for the effects of deregulation on short-run supply in the future. Because of the negative social factors involved with nuclear fuel, increases in price will probably not bring about the increase in reserves that were predicted in the early seventies thereby making supply less elastic. Coal, having received much attention as of late, is probably more elastic than earlier data would indicate (government support and encouragement).

The elasticities are ranked (± .1) in order to reflect some difference in supply. Coal is the most elastic (.6) due to government encouragement and the labor intensity involved in mining (remembering that this is short-run, it is easier to increase coal output through the addition of miners). Oil and natural gas (.5) are next due to the time involved in delivering and setting-up equipment necessary for additional recovery from known reserves (also those methods of recovery, both secondary and tirtiary, involve the use of petroleum base products and therefore, require larger increases in price before they would be used in the recovery of additional fuel)(Merklein and Hardy 1977). The elasticity of supply for nuclear fuel (.4) is lower than the others because of the time involved in extraction and processing of the fuel (required before it can be used in electrical generation).

Given the variance in the elasticities that could be assigned for each fuel supply, several runs of the model were made using high and low estimates of supply holding all other values constant. Over the 16 year period the model covered, there was very little variance in final energy prices for each sector. There was some difference in the quantity of fuels consumed, most noticeable in the residential sector, when lower elasticities of supply was used. The long term trend of a move away from petroleum and toward natural gas in the residential sector still remained.

Generally, the results show that the model is relatively insensitive to various calculations of inelastic supply. The importance of the supply elasticities lie in whether they are either elastic or inelastic. Given the conditions described, it can be assumed that supply is inelastic.

DEMAND ELASTICITIES

Elasticity of demand can be defined in the same manner as supply,

$$E_D = \frac{dQ_D}{dP} \times \frac{P}{Q_D} = \frac{\%\Delta Q_D}{\%\Delta P}$$

as the percentage change in quantity demanded given some percentage change in price. The model requires the long-run elasticity of demand and this is assumed to be relatively inelastic (McNamara and Martin 1979). While it is generally assumed that demand is somewhat more elastic in the long-run than the data in Table 7, this is probably not the case today. It would seem that most adjustments in demand have been made as a result of the 1973 and 1979 increases in energy prices. Additionally, most demand elasticities are calculated for a single fuel. Here, the model requires long-run elasticity of demand for energy in general, not just for one form of fuel. It would be expected that while the demand for any one fuel might be elastic, the demand for energy would be inelastic. The elasticities used are consistent with established data (Hausman 1975, p. 542).

TABLE 7

DEMAND ELASTICITIES

Sector	Elasticities
Residential	.50
Commercial	.45
Industrial	.60
Electric	.50

Industrial demand is rated slightly more elastic than the other sectors primarily due to industries' ability to alter fuel consumption by altering output. The commercial sector demand is somewhat less elastic than the others due to relatively fixed operating hour fuel requirements.

As in supply, due to the variance in the values that could be assigned to demand elasticities, several runs of the model were made using high and low estimates of demand elasticity. There was little variance in long-term prices or trends. The conclusion is that the model is relatively insensitive to various calculations of inelastic demand. The importance of demand elasticities lies in whether they are elastic or inelastic.

DEMAND GROWTH

TABLE 8

DEMAND GROWTH IN FLORIDA

Sector	Average Annual Growth Rate	
	High	Low
Residential	3.5%	2.5%
Commercial	3.0%	2.0%
Industrial	2.0%	1.0%
Electric	5.0%	4.0%

Demand growth is the expected average annual increase in energy consumption for each sector. Two estimates of this are used in the model: a high and a low estimate for each sector. The high estimate for the residential, commercial, and industrial sectors is consistent with the data presented in Table 9.

TABLE 9

ENERGY CONSUMPTION: AMOUNT CONSUMED BY SECTOR IN FLORIDA, SELECTED YEARS 1974 THROUGH 1990

(ROUNDED TO TRILLIONS OF BTUS)

Sector	Historical					Projected
	1974	1975	1976	1977	1978	1990
Residential	429.3	445.8	459.1	494.5	524.6	716.9
Commercial	298.9	316.5	333.5	353.9	376.3	537.0
Industrial	270.1	252.1	302.0	337.0	356.9	413.7

SOURCE: Thompson, Ralph B., ed., Florida Statistical Abstract (Gainesville, Florida: The University Presses of Florida, 1979), Table 15.91, p. 358.

The high estimate for electrical consumption is consistent with projections made by the Florida Public Service Commission (Public Service Commission 1979). Given a decrease in mobility, increasing housing costs, and the possibility of a higher than expected increase in the price of energy, it is possible that estimates, based on projections which are already a year old, may be too high. Therefore, a lower demand growth is also used. This estimate is determined by simply subtracting one percentage point from the high estimate.

TABLE 10

CAPACITY GROWTH

Growth	Fuel			
	Petroleum	Natural Gas	Nuclear	Coal
Capacity Growth	.02	-.001	.0	.03

The capacity growth values in the model are intended to reflect some increase in the production capacity of fuel in the area. Because very little of the fuel used in the area is produced here, the values are relatively small and reflect an increase or decrease in use, storage, and possible increases in refinement capability in the future.

RESERVE DEPLETION RATES

The reserve depletion rates are based on the long-run marginal costs of the productions of various fuels. It is representative of the change in consumption that can take place without a change in cost. The long-run marginal cost curve for each fuel is relatively flat (Anderson and DeHaven 1975). The model assumes that an increase in consumption of 50,000 BTUs would bring about a .001\$/10^6 BTU increase in cost. The effect of this variable was tested by cutting consumption to 25,000 BTUs. This test had no statistical effect on the model's predictions. It is therefore assumed, given the relative flatness of the marginal cost curves for the fuels, that a relatively large change in consumption would be necessary to bring about a change in price.

CHAPTER III

ANALYSIS OF THE RESULTS

Three cases of future energy prices are established for each sector. These cases are established through the use of differing average annual energy price inflation rates. Inflation rates of 5% and 6% are used for the best case estimation, 7% and 8% for the expected case estimation, and 9% and 10% rates of inflation are used for worst case estimations. The price data for each sector tends to indicate a low inflation rate. However, it should be noted that the price increases of 1979 are not included. Those increases would raise the inflation rate.

Using two inflation rates for each case establishes some range within which sector energy prices should fall (in the electrical sector the same is true with the exception being that the price given is the price paid by the other three sectors for electricity). In addition, two average annual growth rates are used for each year at each inflation rate, for each sector which increases the price range and varies fuel consumption to a degree.

All three cases assume that prices are not flexible downward as is logically expected when dealing with depletable resources. The best case scenario assumes that over the time period involved, energy prices will increase slowly in a relatively stable market in both supply and demand. The expected case scenario allows for greater increases in prices in a less stable market. That is, these prices are more probable given oil deregulation, interruptions of foreign oil, and actions by producers both domestic and foreign, that would serve to increase price. Control of foreign supplies and of various international upheavals, as we have learned, is relatively impossible. So are the prediction of those events. Therefore, the third or worst case is based on both the variable involved in the best and expected cases and more frequent disruptions of the energy market caused by variables that are both endogenous and exogenous to the market. In short, the predictions of the model are based on conditions as they are now, which are subject to change. A change in one or more of the assumptions, or the appearance of a variable which significantly alters prices and is not in the model, will change those predictions. Therefore, three different scenarios are established in anticipation of these problems.

Residential fuel consumption in the base year, 1978, was a total of 44.6 trillion BTUs. Approximately half of this was petroleum and half was natural gas. In the case of an average annual growth rate of 3.5%, residential use of petroleum declines at a rate of about one trillion BTUs per year while natural gas usage increases at about the same rate (Tables 11 and 12). With a growth rate of 2.5%, the consumption of petroleum declines slightly quicker and the increase in natural gas is a little slower.

TABLE 11

RESIDENTIAL FUEL CONSUMPTION AND FINAL ENERGY PRICES AT 3.5% ANNUAL GROWTH IN CONSTANT DOLLAR PRICES

Consumption Final Energy Prices	Year 1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fuel Consumption in 10^{12} BTUs																	
Petroleum	*22.2	21	20	19	19	18	17	16	15	14	13	12	11	Ø	Ø	Ø	Ø
Natural Gas	*22.4	23	25	26	27	28	29	30	31	33	34	35	36	37	38	38	38
Final Energy Prices in $\$/10^6$ BTUs																	
5% Annual Average Inflation	2.14	2.27	2.41	2.56	2.71	2.88	3.06	3.24	3.44	3.65	3.88	4.11	4.37	4.64	4.88	5.14	5.42
6% Annual Average Inflation	2.14	2.29	2.46	2.63	2.82	3.03	3.24	3.48	3.73	3.00	3.28	4.59	4.92	5.28	5.62	5.98	6.36
7% Annual Average Inflation	2.14	2.32	2.51	2.72	2.94	3.18	3.45	3.73	4.04	4.37	4.74	5.13	5.55	6.01	6.46	6.94	7.46
8% Annual Average Inflation	2.14	2.34	2.56	2.80	3.06	3.35	3.66	4.00	4.38	4.79	5.23	5.72	6.26	6.85	7.43	8.07	8.76
9% Annual Average Inflation	2.14	2.36	2.61	2.88	3.18	3.52	3.88	4.29	4.74	5.24	5.78	6.39	7.06	7.80	8.55	9.37	10.28
10% Annual Average Inflation	2.14	2.39	2.66	2.97	3.31	3.70	4.13	4.60	5.13	5.73	6.39	7.13	7.96	8.88	9.83	10.89	12.06

*Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

TABLE 17

RESIDENTIAL FUEL CONSUMPTION AND FINAL ENERGY PRICES AT 2.5% ANNUAL GROWTH IN CONSTANT DOLLAR PRICES

Consumption Final Energy Prices	Year 1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fuel Consumption in 10^{12} BTUs																	
Petroleum	*22.2	21	20	19	18	17	16	15	14	13	12	11	10	ø	ø	ø	ø
Natural Gas	*22.4	23	24	26	27	28	29	30	31	32	33	34	36	37	37	37	37
Final Energy Prices in $\$/10^6$ BTUs																	
5% Annual Average Inflation	2.14	2.27	2.41	2.55	2.71	2.87	3.05	3.23	3.43	3.64	3.86	4.10	4.35	4.61	4.86	5.11	5.38
6% Annual Average Inflation	2.14	2.29	2.46	2.63	2.82	3.02	3.24	3.47	3.72	3.98	4.27	4.57	4.90	5.25	5.59	5.94	6.32
7% Annual Average Inflation	2.14	2.32	2.51	2.71	2.94	3.18	3.44	3.72	4.03	4.36	4.72	5.11	5.53	5.98	6.43	6.90	7.41
8% Annual Average Inflation	2.14	2.34	2.56	2.79	3.05	3.34	3.65	3.99	4.36	4.77	5.21	5.70	6.23	6.81	7.39	8.02	8.70
9% Annual Average Inflation	2.14	2.36	2.61	2.88	3.18	3.51	3.88	4.28	4.73	5.22	5.76	6.36	7.03	7.76	8.50	9.32	10.21
10% Annual Average Inflation	2.14	2.39	2.66	2.97	3.31	3.69	4.12	4.59	5.12	5.71	6.37	7.10	7.92	8.84	9.78	10.82	11.95

*Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

Residential energy prices in the best case estimation increase from 2.14$/10^6$ BTU, to somewhere between 5.42 and 6.36$/10^6$ BTU, representing a two to three fold increase over the 17 year period covered. In the expected case estimation, prices show a 3.5 to 4 fold increase with the expected price falling somewhere in a range between 7.46 and 8.76$/10^6$ BTUs. Best case prices are reached in the years 1989 and 1990, some five to six years earlier. In the estimation of the third, or worst case, prices increase 5 to 6 fold falling somewhere in a range between 10.28 and 12.06$/10^6$ BTU. In this estimation, best area prices are reached six to eight years earlier (1987 - 1989). The same relationship between the three cases are true given a demand growth of 2.5% with the exception that prices are between four to eight cents per million BTUs lower. Logically any solar innovation, based on price alone, should come about two to three years earlier in the worst case and some five to six years later in the best case, than in the expected case. Also, the use of any solar technology will come about more quickly given a higher annual average growth, which is generally true in the other sectors as well (commercial and industrial).

The same conclusions can be drawn for the commercial sector that were drawn for the residential sector. The trend is a move away from the use of petroleum and a move toward natural gas (Tables 13 and 14). Again, the decline in the amount of petroleum consumed was slower in the higher growth case than in the lower case while natural gas consumption increased more quickly in the

TABLE 13

COMMERCIAL FUEL CONSUMPTION AND FINAL ENERGY PRICES AT 3.0% ANNUAL GROWTH IN CONSTANT DOLLAR PRICES

Consumption / Final Energy Prices	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fuel Consumption in 10^{12} BTUs																	
Petroleum	42	41	41	40	39	38	38	37	36	35	35	34	33	32	31	31	30
Natural Gas	28	29	30	31	32	32	33	34	35	36	37	38	39	40	40	41	42
Final Energy Prices in $/$10^6$ BTUs																	
5% Annual Average Inflation	1.72	1.83	1.95	2.08	2.21	2.36	2.51	2.67	2.84	3.03	3.88	3.43	3.66	3.89	4.15	4.41	4.70
6% Annual Average Inflation	1.72	1.85	1.99	2.14	2.30	2.48	2.66	2.86	3.08	3.31	3.56	3.83	4.12	4.43	4.77	5.13	5.52
7% Annual Average Inflation	1.72	1.87	2.03	2.21	2.40	2.60	2.83	3.07	3.34	3.63	3.94	4.28	4.65	5.05	5.49	5.96	6.47
8% Annual Average Inflation	1.72	1.89	2.07	2.27	2.49	2.74	3.00	3.29	3.62	3.97	4.35	4.78	5.24	5.75	6.31	6.92	7.60
9% Annual Average Inflation	1.72	1.91	2.11	2.34	2.60	2.88	3.19	3.53	3.92	4.34	4.81	5.33	5.91	6.55	7.26	8.04	8.91
10% Annual Average Inflation	1.72	1.93	2.16	2.41	2.70	3.02	3.39	3.79	4.24	4.75	5.32	5.95	6.66	7.46	8.35	9.35	10.46

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

TABLE 14

COMMERCIAL FUEL CONSUMPTION AND FINAL ENERGY PRICES AT 2.0% ANNUAL GROWTH IN CONSTANT DOLLAR PRICES

Consumption / Final Energy Prices	Year 1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fuel Consumption[2] in 10^{12} BTUs																	
Petroleum	42	41	40	40	39	38	37	36	36	35	34	33	32	31	30	29	28
Natural Gas	28	29	30	31	31	32	33	34	35	35	36	37	38	39	40	41	42
Final Energy Prices in $\$/10^6$ BTUs																	
5% Annual Average Inflation	1.72	1.83	1.95	2.07	2.21	2.35	2.50	2.66	2.83	3.01	3.20	3.41	3.62	3.86	4.10	4.37	4.65
6% Annual Average Inflation	1.72	1.85	1.99	2.14	2.30	2.47	2.65	2.85	3.06	3.29	3.54	3.80	4.09	4.39	4.72	5.07	5.45
7% Annual Average Inflation	1.72	1.87	2.03	2.20	2.39	2.59	2.82	3.06	3.32	3.60	3.91	4.24	4.61	5.00	5.43	5.90	6.40
8% Annual Average Inflation	1.72	1.89	2.07	2.27	2.49	2.73	2.99	3.28	3.59	3.94	4.32	4.74	5.20	5.70	6.25	6.85	7.51
9% Annual Average Inflation	1.72	1.90	2.11	2.34	2.59	2.87	3.17	3.52	3.89	4.31	4.78	5.29	5.86	6.49	7.19	7.96	8.81
10% Annual Average Inflation	1.72	1.92	2.15	2.41	2.69	3.01	3.37	3.77	4.22	4.72	5.28	5.90	6.61	7.39	8.27	9.25	10.34

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

higher growth case than in the lower growth case (years 1982, 1987 and 1989).

Best case prices for 1994 fall somewhere between 4.70 and 5.52$/10^6$ BTU, expected prices fall between 6.47 and 7.60$/10^6$ BTU, and worst case prices fall between 8.91 and 10.46$/10^6$ BTUs (estimates are based on a initial price of 1.72$/10^6$ BTUs). Best case prices occur four to five years earlier in the expected case and seven to eight years earlier in the worst case scenario. Prices for the lower growth rate exhibit the same relationship, with the exception being that prices range five to eleven cents lower in the last year.

In the industrial sector at a two percent growth rate, the general trend is a move away from petroleum use and an increase in natural gas use. Coal, due mainly to the fact that its marginal productivity is so low compared to petroleum and natural gas, is eliminated after the first year. Price seems to be the major influence in the long term trends since there is little difference in the marginal productivities of petroleum and natural gas. It is probable that the industrial use of coal will increase rather than decrease because of price and long-term availability of the fuel which the latter is not taken into account by the model. In the simulation using a growth rate of 1%, the same trends persist. Because of the lower growth rate, petroleum consumption decreases more quickly and natural gas consumption increases more slowly than in the two percent growth simulation (Tables 15 and 16).

Industrial energy prices increase from 1.0$/10^6$ BTU in 1978

TABLE 15

INDUSTRIAL FUEL CONSUMPTION AND FINAL ENERGY PRICES AT 2.0% ANNUAL GROWTH IN CONSTANT DOLLAR PRICES

Consumption Final Energy Prices	Year																
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fuel Consumption² in 10^{12} BTUs																	
Petroleum	110	110	110	109	109	109	108	108	107	107	106	106	106	105	105	104	103
Natural Gas	77	78	79	80	81	83	84	85	86	87	88	89	90	91	92	94	95
Coal	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Final Energy Prices in $\$/10^6$ BTUs																	
5% Annual Average Inflation	1.00	1.07	1.14	1.22	1.31	1.40	1.49	1.59	1.70	1.82	1.94	2.07	2.22	2.37	2.53	2.70	2.87
6% Annual Average Inflation	1.00	1.08	1.17	1.26	1.36	1.47	1.58	1.71	1.84	1.99	2.15	2.32	2.50	2.70	2.91	3.14	3.37
7% Annual Average Inflation	1.00	1.09	1.19	1.30	1.41	1.54	1.68	1.83	2.00	2.18	2.37	2.59	2.82	3.07	3.35	3.64	3.96
8% Annual Average Inflation	1.00	1.10	1.21	1.34	1.47	1.62	1.78	1.97	2.16	2.38	2.62	2.89	3.18	3.50	3.85	4.23	4.64
9% Annual Average Inflation	1.00	1.11	1.24	1.38	1.53	1.70	1.90	2.11	2.34	2.61	2.90	3.22	3.58	3.98	4.43	4.92	5.45
10% Annual Average Inflation	1.00	1.12	1.26	1.42	1.59	1.79	2.01	2.26	2.54	2.85	3.20	3.60	4.04	4.53	5.09	5.72	6.39

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

TABLE 16

INDUSTRIAL FUEL CONSUMPTION AND FINAL ENERGY PRICES AT 1.0% ANNUAL GROWTH IN CONSTANT DOLLAR PRICES

Consumption Final Energy Prices	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fuel Consumption[2] in 10^{12} BTUs																	
Petroleum	110	110	109	109	108	108	107	106	106	105	104	103	102	101	100	98	97
Natural Gas	77	78	79	80	81	82	83	84	84	85	86	87	87	88	89	89	90
Coal	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Final Energy Prices in $/$10^6$ BTUs																	
5% Annual Average Inflation	1.00	1.07	1.14	1.21	1.29	1.38	1.47	1.57	1.67	1.78	1.89	2.01	2.13	2.26	2.40	2.55	2.71
6% Annual Average Inflation	1.00	1.08	1.16	1.25	1.35	1.45	1.56	1.68	1.81	1.95	2.09	2.24	2.40	2.58	2.76	2.96	3.17
7% Annual Average Inflation	1.00	1.09	1.18	1.29	1.40	1.52	1.66	1.80	1.96	2.13	2.31	2.50	2.71	2.93	3.18	3.44	3.73
8% Annual Average Inflation	1.00	1.10	1.21	1.33	1.46	1.60	1.76	1.93	2.12	2.33	2.55	2.79	3.05	3.34	3.65	4.00	4.37
9% Annual Average Inflation	1.00	1.11	1.23	1.37	1.52	1.68	1.87	2.07	2.30	2.55	2.82	3.12	3.44	3.81	4.20	4.64	5.13
10% Annual Average Inflation	1.00	1.12	1.26	1.41	1.58	1.77	1.98	2.22	2.49	2.79	3.12	3.48	3.88	4.33	4.84	5.40	6.02

SOURCE: Florida, Department of Economics, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

to somewhere between 2.87 and 3.37$/$10^6$ BTU in 1994 in the best case situation. In the expected case, final prices (1994) range between 3.96 and 4.64$/$10^6$ BTU while in the worst case final prices range between 5.45 and 6.39$/$10^6$ BTU. In the expected case, estimation best case prices are arrived at some three to five years earlier (1990 - 1992). In the worst case simulation, best case prices are arrived at some six to seven years earlier. This relationship, as in the other sectors, is basically a result of the inflation rate used. In the lower growth case (1%), the same relationships exist with the exception being that prices are between 16 and 37 cents lower than in the higher growth rate case.

Four fuels are used for electrical production; petroleum, natural gas, nuclear and coal. The use of all four fuels increase (in the other sectors petroleum use decreased) over the time period covered by the model. It is more useful here to look at the percentage increase in fuel consumption. Over the period of the model, petroleum consumption increased by 4.5%, coal increased 6.5%, natural gas usage increased 32%, and nuclear increased 83%. The two major increases are in natural gas and nuclear. In the case of nuclear, this large increase is a function of the price of nuclear fuel (relatively cheap). The marginal productivity of nuclear fuel, when it is used as a fuel in the production of electricity, is somewhat lower than the other fuels but its price is so much lower than the other fuels that the effect of the lower marginal productivity is nulified. Natural gas use also increases due to low price and a high marginal productivity. These findings do not reflect the same trends as other studies and conditions indicate.

The National Electric Reliability Council (NERC) reports show that natural gas consumption for electrical generation will decrease from 144.456×10^6 MCF in 1978 to 16.351×10^6 MCF in 1988. This is opposite of what the model indicates. Coal use is expected to increase by about 390% between 1978 and 1988 instead of the 6.5% given by the model (National Electric Reliability Council 1979).

Nuclear, based on price alone, should follow the trend indicated. However, with the recent negative social connotations attached to nuclear, it is highly probable that the growth of nuclear power may be zero. If nothing else, the time lag involved in setting-up nuclear generation of electricity (licensing, studies, etc.), is almost as long as the time period covered by the model.

The significance of this is reflected in the price. If there is not a significant increase in the use of nuclear fuel for generating electricity, due to social inhibitions, the price of electricity will be significantly higher. The price would be higher because nuclear fuel is much cheaper than the other fuels, which would replace it even though coal and natural gas are relatively inexpensive fuels when compared to oil.

Prices for electricity follow the same patterns as they do for energy in the other sectors. Best case estimations range between 18.50 and 21.71$/10^6$ BTU in 1994. Expected case estimations for 1994 range between 25.47 and 29.89$/10^6$ BTU, and worst case

TABLE 17

ELECTRIC FUEL CONSUMPTION AND FINAL ENERGY PRICES AT 5.0% ANNUAL GROWTH IN CONSTANT DOLLAR PRICES

Consumption / Final Energy Prices	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fuel Consumption[2] in 10^{12} BTUs																	
Petroleum	483	485	486	488	489	490	492	493	495	496	497	499	500	501	503	504	505
Natural Gas	161	164	166	169	172	175	178	181	184	188	191	194	198	201	205	208	212
Nuclear	170	178	185	193	202	210	218	227	236	244	253	263	272	281	291	301	311
Coal	169	170	171	172	172	173	174	175	176	176	177	178	178	179	179	180	180
Final Energy Prices in $\$/10^6$ BTUs																	
5% Annual Average Inflation	6.22	6.22	7.13	7.63	8.17	8.75	9.37	10.03	10.74	11.49	12.30	13.17	14.09	15.09	16.15	17.28	18.50
6% Annual Average Inflation	6.22	6.73	7.27	7.87	8.51	9.20	9.95	10.76	11.63	12.51	13.60	14.70	15.89	17.18	18.57	20.08	21.71
7% Annual Average Inflation	6.22	6.79	7.92	8.11	8.85	9.67	10.56	11.59	12.60	13.76	15.02	16.41	17.92	19.57	21.36	23.33	25.47
8% Annual Average Inflation	6.22	6.86	7.57	8.35	9.22	10.17	11.21	12.37	13.65	15.05	16.61	18.32	20.20	22.28	24.58	27.10	29.89
9% Annual Average Inflation	6.22	6.93	7.72	8.61	9.53	10.69	11.91	13.27	14.78	16.47	18.35	20.45	22.78	25.38	28.27	31.49	35.08
10% Annual Average Inflation	6.22	7.00	7.88	8.87	9.98	11.24	12.64	14.23	16.02	18.02	20.28	22.82	25.68	28.90	32.52	36.59	41.16

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

TABLE 18

ELECTRIC FUEL CONSUMPTION AND FINAL ENERGY PRICES AT 4.0% ANNUAL GROWTH IN CONSTANT DOLLAR PRICES

Consumption / Final Energy Prices	Year																
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Fuel Consumption[2] in 10^{12} BTUs																	
Petroleum	483	484	485	486	487	488	488	489	490	491	491	492	493	493	494	495	495
Natural Gas	161	163	165	168	170	173	175	178	180	183	186	188	191	194	197	200	203
Nuclear	170	176	183	189	196	203	210	217	224	231	239	246	254	261	269	277	285
Coal	169	169	170	171	171	172	172	173	173	173	174	174	174	175	175	175	175
Final Energy Prices in $\$/10^6$ BTUs																	
5% Annual Average Inflation	6.22	6.64	7.09	7.57	8.09	8.62	9.20	9.83	10.49	11.19	11.95	12.75	13.61	14.53	15.51	16.55	17.67
6% Annual Average Inflation	6.22	6.71	7.23	7.80	8.41	9.06	9.77	10.54	11.36	12.25	13.21	14.24	15.35	16.55	17.84	19.23	20.73
7% Annual Average Inflation	6.22	6.77	7.37	8.03	8.75	9.53	10.38	11.30	12.31	13.40	14.60	15.89	17.31	18.85	20.52	22.35	24.33
8% Annual Average Inflation	6.22	6.84	7.53	8.28	9.11	10.02	11.02	12.12	13.33	14.66	16.13	17.74	19.51	21.46	23.61	25.96	28.55
9% Annual Average Inflation	6.22	6.91	7.68	8.53	9.48	10.53	11.70	13.00	14.44	16.05	17.83	19.80	22.00	24.44	27.15	30.16	33.51
10% Annual Average Inflation	6.22	6.98	7.83	8.79	9.87	11.07	12.42	13.94	15.65	17.56	19.70	22.11	24.31	27.44	31.23	35.04	39.32

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

estimations range between 35.08 and 41.16$/10^6 BTUs. In the expected case scenario, best case prices for 1994 are reached some five to six years earlier; 1989 - 1990. In the worst case scenario, best case prices for 1994 are reached some 6 to 7 years earlier; 1988 - 1989 (data in Tables 17 and 18).

In 1978, in constant dollars and given a 5% annual average growth, the average cost of 1000 KWhrs. of electricity was about $21.20. By 1994, given a 5% annual average growth, that dollar value will increase to a point somewhere between $63.10/1000 KWhr. and $140.40/1000 KWhr. Given that the value of the dollar decreased in value by a little more than one half between 1967 and 1978, and that it is not unlikely that this will occur again between 1978 and 1994, it can be assumed that real dollar values for electricity, that is the dollar value unadjusted for inflation, will range somewhere between $252/1000 KWhrs. and $562/1000 KWhrs. in 1994. In the lower demand growth case (4%), constant dollar prices for electricity in 1994 would range between $60.30/1000 KWhrs. and $134.20/1000 KWhrs. The unadjusted value for that same 1000 KWhrs. would fall between $241.20 and $536.80 (lowest best case and highest worst case price estimation). Price data for electricity is listed in Table 19.

TABLE 19

SELECTED PRICES FOR ELECTRICITY: CONSTANT ¢/KWHR.

	Year						
	1978	1980	1983	1985	1988	1990	1994
5% Average Annual Growth Case							
5% Average Annual Inflation	2.12	2.43	2.98	3.42	4.20	4.81	6.31
6% Average Annual Inflation	2.12	2.48	3.14	3.67	4.64	5.42	7.41
7% Average Annual Inflation	2.12	2.53	3.29	3.94	5.12	6.11	8.69
8% Average Annual Inflation	2.12	2.58	3.47	4.22	5.67	6.89	10.19
9% Average Annual Inflation	2.12	2.63	3.65	4.53	6.26	7.77	11.97
10% Average Annual Inflation	2.12	2.69	3.84	4.86	6.92	8.76	14.04
4% Average Annual Growth Case							
5% Average Annual Inflation	2.12	2.42	2.94	3.35	4.08	4.64	6.03
6% Average Annual Inflation	2.12	2.47	3.10	3.59	4.51	5.24	7.10
7% Average Annual Inflation	2.12	2.52	3.25	3.86	4.98	5.91	8.30
8% Average Annual Inflation	2.12	2.57	3.42	4.14	5.50	6.66	9.74
9% Average Annual Inflation	2.12	2.62	3.59	4.44	6.08	7.51	11.43
10% Average Annual Inflation	2.12	2.67	3.78	4.76	6.72	8.47	13.42

KWhr. = 3412 BTUs

CHAPTER IV

PRICING ANALYSIS FOR RESIDENTIAL USE OF SOLAR

Most solar heating is in the form of low-grade heat. A Swiss scientist, Nicolas de Saussure, is given credit for the invention of the flat-plate collector in the eighteenth century (Hayes 1977). More than one third of the money spent on energy by nations is spent on that type of low-grade heat that could be provided by a flat-plate collector. Until they were replaced by low cost gas and electric heaters, solar water heaters were very common in Florida (Hayes 1977). With the recent increases in energy costs, these flat-plate type of collectors are beginning to become more popular. In order to see why it is necessary to estimate the payback periods, or the amount of time it will take to recover the initial costs of the solar system. Payback periods are calculated by estimating the total of the dollar value of the energy saved in each year the system is used.

Several assumptions are made before actually calculating payback periods. It is assumed that the average single family residence is 1500 square feet in size, that it has a constant load of 80 gallons of water per day to be heated 60^{0} F (for hot water heating), and that it has a thermal load, for space heating of 10 BTU/DD/ft^2. "Thermal load is defined as the total heat required by the building per day per degree farenheit temperature difference between the inside temperature and the outside temperature" (Joint Economic Committee, Congress of the United States 1977). Given this data, it is possible to staze collector size required for various percentage substitution of solar for conventional fuels. These are listed in Table 20.

For Florida, to heat 25% of hot water requirements requires collector area of 11.1 square feet, for 50% requires a collector size of 25.5 square feet, and 75% solar substitution requires a collector size of 47.1 square feet. Sizes for residential space heating are approximately the same. Substitution of solar for 25% of conventional fuel use requires a collector area of 11 square feet, for 50% substitution collector size must be 26 square feet and for 75% collector size must be 50 square feet.

System costs for residential solar water and space heating range between $15.00 to $30 per square foot (Bennington 1978). Variance in price is associated with the differences involved in the quality and type of construction involved with the equipment. In this case, a low figure of $18.00 per square foot will be used. This assumes that a medium quality system is bought, the equipment will be paid for in cash thereby eliminating any additional costs incurred through financing and that the consumer takes advantage of available tax credits (also assumes a $1, constant, increase in price between 1978 and 1980). These dollar figures are in current dollar values. The calculated cost for energy is in terms of con-

TABLE 20

Collector Area Requirements* for 25, 50, and 75 Percent Solar Fraction

State	Residential Space Heat**			Domestic Hot Water***		
	25%	50%	75%	25%	50%	75%
Alabama	98	254	525	12.2	28.1	52.4
Arizona	50	127	255	9.0	20.7	38.6
Arkansas	119	312	634	12.3	28.3	52.9
California	35	93	195	10.2	23.4	43.6
Colorado	126	218	651	16.2	39.3	62.4
Connecticut	154	405	842	18.5	44.9	71.4
Delaware	155	407	850	12.9	29.7	55.9
Florida	11	26	50	11.1	25.5	47.1
Georgia	98	254	525	12.2	28.1	52.4
Idaho	139	387	867	15.2	36.9	59.0
Illinois	190	506	1064	18.9	45.9	72.9
Indiana	174	473	1009	13.4	44.7	70.9
Iowa	192	506	1059	18.2	44.1	70.0
Kansas	152	396	823	17.6	42.3	68.0
Kentucky	171	459	979	14.0	32.5	61.6
Louisiana	97	252	510	13.4	30.9	58.0
Maine	176	462	964	17.5	42.6	67.6
Maryland	135	348	725	12.4	29.5	53.3
Massachusetts	175	457	948	19.4	47.0	74.7
Michigan	197	537	1139	19.2	47.4	75.3
Minnesota	205	547	1153	17.0	41.3	65.5
Mississippi	97	252	510	13.4	30.9	58.0
Missouri	147	390	819	16.8	40.8	64.3
Montana	161	428	920	15.7	38.2	60.9
Nebraska	168	438	912	16.1	39.2	62.2
Nevada	69	178	361	8.6	19.7	36.7
New Hampshire	236	638	1355	20.3	49.3	78.2
New Jersey	155	407	850	12.9	29.7	55.9
New Mexico	93	236	483	8.7	19.9	36.9
New York	170	443	922	13.5	31.2	58.9
North Carolina	113	288	588	12.2	28.1	52.4
North Dakota	193	520	1100	15.4	37.4	59.4
Ohio	210	586	1281	20.3	49.2	79.0
Oklahoma	111	284	582	11.2	25.6	47.6
Oregon	124	359	827	12.9	30.5	60.1
Pennsylvania	193	518	1101	19.6	47.6	75.6
Rhode Island	155	403	838	18.7	45.4	72.2
South Carolina	71	183	363	11.7	26.7	49.6
South Dakota	154	404	839	15.6	37.8	60.0
Tennessee	128	342	716	12.6	29.1	54.9
Texas	80	205	411	10.9	25.1	46.3
Utah	130	350	751	13.8	33.5	53.1
Vermont	236	638	1355	20.3	49.3	78.2
Virginia	135	346	713	12.5	28.7	53.7
Washington	137	408	984	15.9	37.6	74.6
West Virginia	195	.526	1134	22.0	53.4	85.5
Wisconsin	196	532	1129	17.4	42.3	67.2
Wyoming	141	358	728	15.3	37.2	59.1

*Collector areas are in square feet for each fraction to be provided by solar energy.

**Assuming a 10BTU/DD/ft^2 Single-family Residence (1500 sq. ft.)

***Assuming a constant load of 80 gallons per day to be heated 60°F.

SOURCE: Joint Economic Committee, Congress of the United States, The Economics of Solar Home Heating. Washington, DC: Government Printing Office, 1977, p. 44.

stant dollars. A deflator of 2.0 is used in order to convert solar costs to constant dollar prices (U.S. Bureau of the Census 1979). Therefore, constant dollar costs for residential solar will be $9 per square foot. This makes the system cost $900 for a solar system that would provide 75% of the water and space heating needs for an average residence.

The formula used to calculate the savings received by using solar equipments is (Scott, Melicher and Sciglimpaglia 1974):

$$\sum_{i=1}^{n} (\text{Q Fuel Use})(\text{Substitution Rate})(\text{Cost of Fuel Used})$$

n = Number of Years Required

This formula is calculated each year until the savings realized from solar equal the systems cost. In order to estimate the quantity of fuel used for water and space heating, a factor of .5 could be applied to the average electric consumption and an factor of .72 will be applied to petroleum and natural gas (it would be expected that more of the oil and natural gas supplied to residences would be used for water and space heating because those fuels can be used in few other areas as opposed to electricity which can be used for all applications within the household)(Scott, Melicher and Sciglimpaglia 1974).

In 1974 in the Miami area, average customer consumption of natural gas was 33.3 therms per month (Scott, Melicher and Sciglimpaglia 1974). This was increased to 35 therms per month to account for users in northern sectors of Florida. After converting to BTU (1 term = 100,000 BTUs) and multiplying by a factor of .72, annual consumption of natural gas is 30 x 10^6 BTUs (since this is now in BTUs, and more than half, 68% of petroleum consumption is in the form of LP gas, it will be assumed that this applies to petroleum as well. It is now possible to use the energy price for the residential sector estimated by the model).

For a purchase of solar equipment in 1980, using best case prices, 5% annual inflation, in the annual growth scenario of 3.5%, the initial investment in solar for water and space heating will be recovered by 1990. After that, any money saved could be put towards annual energy costs (other 25% of water and space heating done by petroleum and natural gas). The average life of this type of solar system should be about 25 years (Thompson 1979, p. 352). Tables 21 - 26, expected (7%) and worst (9%) cases in the annual growth scenario of 3.5%, and best (5%), expected (7%), and worst (9%) in the annual growth scenario of 2.5%, reflect the same outcome except with differing payback periods. The higher the energy price, the shorter the payback period.

By using the lower price form the range established for each case, these paybacks are probably overstated. However, the payback periods are consistent with that of other studies.

Tables 21 - 26 show the estimated payback periods for a residential water and space heating system that replaces 75% of water and space heating done by electric. The house size, system

TABLE 21

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING BEST CASE PRICES: 3.5% DEMAND GROWTH SCENARIO FOR PETROLEUM AND NATURAL GAS

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	($30x10^6$ BTU)	($2.41\$/10^6$ BTU)	=	$54.23
1981	(.75)	($30x10^6$ BTU)	($2.56\$/10^6$ BTU)	=	57.60
1982	(.75)	($30x10^6$ BTU)	($2.71\$/10^6$ BTU)	=	60.98
1983	(.75)	($30x10^6$ BTU)	($2.88\$/10^6$ BTU)	=	64.80
1984	(.75)	($30x10^6$ BTU)	($3.06\$/10^6$ BTU)	=	68.85
1985	(.75)	($30x10^6$ BTU)	($3.24\$/10^6$ BTU)	=	72.90
1986	(.75)	($30x10^6$ BTU)	($3.44\$/10^6$ BTU)	=	77.40
1987	(.75)	($30x10^6$ BTU)	($3.65\$/10^6$ BTU)	=	82.13
1988	(.75)	($30x10^6$ BTU)	($3.88\$/10^6$ BTU)	=	87.30
1989	(.75)	($30x10^6$ BTU)	($4.11\$/10^6$ BTU)	=	92.48
1990	(.75)	($30x10^6$ BTU)	($4.37\$/10^6$ BTU)	=	98.33
1991	(.75)	($30x10^6$ BTU)	($4.64\$/10^6$ BTU)	=	104.40
			TOTAL SAVINGS		$921.00 (Rounded)
			(12 Year Payback)		

The estimated payback period for solar investment is 12 years when substituting solar for 75% of the petroleum and natural gas normally used, using best case price estimations assuming a 3.5% demand growth.

TABLE 22

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING EXPECTED CASE PRICES:

3.5% DEMAND GROWTH SCENARIO FOR

PETROLEUM AND NATURAL GAS

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	($30x10^6$ BTU)	($2.51\$/10^6$ BTUs)	=	$56.48
1981	(.75)	($30x10^6$ BTU)	($2.72\$/10^6$ BTUs)	=	61.20
1982	(.75)	($30x10^6$ BTU)	($2.94\$/10^6$ BTUs)	=	66.15
1983	(.75)	($30x10^6$ BTU)	($3.18\$/10^6$ BTUs)	=	71.55
1984	(.75)	($30x10^6$ BTU)	($3.45\$/10^6$ BTUs)	=	77.625
1985	(.75)	($30x10^6$ BTU)	($3.73\$/10^6$ BTUs)	=	83.925
1986	(.75)	($30x10^6$ BTU)	($4.04\$/10^6$ BTUs)	=	90.90
1987	(.75)	($30x10^6$ BTU)	($4.37\$/10^6$ BTUs)	=	98.33
1988	(.75)	($30x10^6$ BTU)	($4.74\$/10^6$ BTUs)	=	106.65
1989	(.75)	($30x10^6$ BTU)	($5.13\$/10^6$ BTUs)	=	115.43
1990	(.75)	($30x10^6$ BTU)	($5.55\$/10^6$ BTUs)	=	124.875
			TOTAL SAVINGS		$953.100
			(11 year payback)		

The estimated payback period for solar investment is 11 years when substituting solar for 75% of the petroleum and natural gas normally used, using expected case price estimations assuming a 3.5% demand growth.

TABLE 23

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING WORST CASE PRICES: 3.5% DEMAND GROWTH SCENARIO FOR PETROLEUM AND NATURAL GAS

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	($30x10^6$ BTU)	($2.61\$/10^6$ BTUs)	=	\$58.73
1981	(.75)	($30x10^6$ BTU)	($2.88\$/10^6$ BTUs)	=	64.80
1982	(.75)	($30x10^6$ BTU)	($3.18\$/10^6$ BTUs)	=	71.55
1983	(.75)	($30x10^6$ BTU)	($3.52\$/10^6$ BTUs)	=	79.20
1984	(.75)	($30x10^6$ BTU)	($3.88\$/10^6$ BTUs)	=	87.30
1985	(.75)	($30x10^6$ BTU)	($4.29\$/10^6$ BTUs)	=	96.53
1986	(.75)	($30x10^6$ BTU)	($4.74\$/10^6$ BTUs)	=	106.65
1987	(.75)	($30x10^6$ BTU)	($5.24\$/10^6$ BTUs)	=	117.90
1988	(.75)	($30x10^6$ BTU)	($5.78\$/10^6$ BTUs)	=	130.05
1989	(.75)	($30x10^6$ BTU)	($6.39\$/10^6$ BTUs)	=	143.775
			TOTAL SAVINGS (10 year payback)		\$956.880

The estimated payback period for solar investment is 10 years when substituting solar for 75% of the petroleum and natural gas normally used, using worst case price estimations assuming a 3.5% demand growth.

TABLE 24

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING BEST CASE PRICES: 2.5% DEMAND GROWTH SCENARIO FOR PETROLEUM AND NATURAL GAS

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	(30×10^6 BTU)	($2.41\$/10^6$ BTUs)	=	\$54.23
1981	(.75)	(30×10^6 BTU)	($2.55\$/10^6$ BTUs)	=	57.38
1982	(.75)	(30×10^6 BTU)	($2.71\$/10^6$ BTUs)	=	60.98
1983	(.75)	(30×10^6 BTU)	($2.87\$/10^6$ BTUs)	=	64.58
1984	(.75)	(30×10^6 BTU)	($3.05\$/10^6$ BTUs)	=	68.63
1985	(.75)	(30×10^6 BTU)	($3.23\$/10^6$ BTUs)	=	72.68
1986	(.75)	(30×10^6 BTU)	($3.43\$/10^6$ BTUs)	=	77.175
1987	(.75)	(30×10^6 BTU)	($3.64\$/10^6$ BTUs)	=	81.90
1988	(.75)	(30×10^6 BTU)	($3.86\$/10^6$ BTUs)	=	86.85
1989	(.75)	(30×10^6 BTU)	($4.10\$/10^6$ BTUs)	=	92.25
1990	(.75)	(30×10^6 BTU)	($4.35\$/10^6$ BTUs)	=	97.88
1991	(.75)	(30×10^6 BTU)	($4.61\$/10^6$ BTUs)	=	103.73
			TOTAL SAVINGS (12 year payback)		\$918.24

The estimated payback period for solar investment is 12 years when substituting solar for 75% of the petroleum and natural gas normally used, using best case price estimations assuming a 2.5% demand growth.

TABLE 25

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING EXPECTED CASE PRICES: 2.5% DEMAND GROWTH SCENARIO FOR PETROLEUM AND NATURAL GAS

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	(30×10^6 BTU)	(2.51\$/10^6 BTUs)	=	\$56.48
1981	(.75)	(30×10^6 BTU)	(2.71\$/10^6 BTUs)	=	60.98
1982	(.75)	(30×10^6 BTU)	(2.94\$/10^6 BTUs)	=	66.15
1983	(.75)	(30×10^6 BTU)	(3.18\$/10^6 BTUs)	=	71.55
1984	(.75)	(30×10^6 BTU)	(3.44\$/10^6 BTUs)	=	77.40
1985	(.75)	(30×10^6 BTU)	(3.72\$/10^6 BTUs)	=	83.70
1986	(.75)	(30×10^6 BTU)	(4.03\$/10^6 BTUs)	=	90.68
1987	(.75)	(30×10^6 BTU)	(4.36\$/10^6 BTUs)	=	98.10
1988	(.75)	(30×10^6 BTU)	(4.72\$/10^6 BTUs)	=	106.20
1989	(.75)	(30×10^6 BTU)	(5.11\$/10^6 BTUs)	=	114.98
1990	(.75)	(30×10^6 BTU)	(5.53\$/10^6 BTUs)	=	124.43
			TOTAL SAVINGS		\$950.63
			(11 payback periods)		

The estimated payback period for solar investment is 11 years when substituting solar for 75% of the petroleum and natural gas normally used, using expected case price estimations assuming a 2.5% demand growth.

TABLE 26

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING WORST CASE PRICES:

2.5% DEMAND GROWTH SCENARIO FOR

PETROLEUM AND NATURAL GAS

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	($30x10^6$ BTU)	($2.61\$/10^6$ BTUs)	=	$58.73
1981	(.75)	($30x10^6$ BTU)	($2.88\$/10^6$ BTUs)	=	64.80
1982	(.75)	($30x10^6$ BTU)	($3.18\$/10^6$ BTUs)	=	71.55
1983	(.75)	($30x10^6$ BTU)	($3.51\$/10^6$ BTUs)	=	78.98
1984	(.75)	($30x10^6$ BTU)	($3.88\$/10^6$ BTUs)	=	87.30
1985	(.75)	($30x10^6$ BTU)	($4.28\$/10^6$ BTUs)	=	96.30
1986	(.75)	($30x10^6$ BTU)	($4.73\$/10^6$ BTUs)	=	106.43
1987	(.75)	($30x10^6$ BTU)	($5.22\$/10^6$ BTUs)	=	117.45
1988	(.75)	($30x10^6$ BTU)	($5.76\$/10^6$ BTUs)	=	129.60
1989	(.75)	($30x10^6$ BTU)	($6.36\$/10^6$ BTUs)	=	140.85
			TOTAL SAVINGS (10 payback periods)	=	$951.975

The estimated payback period for solar investment is 10 years when substituting solar for 75% of the petroleum and natural gas normally used, using worst case price estimations assuming a 2.5% demand growth.

cost and payback calculations are the same as they were for natural gas and petroleum. It is assumed that 50% of electricity used in a residence is used for water and space heating.

Using the average annual electric consumption per customer gives a value of 5429 KWhrs. per year (Lottman 1980). That number of KWhrs. generally under states the actual KWhr. consumption. For a single individual heating 20 gallons of water per day could expect to use 130 KWhrs. per month to heat that water 60-65^{0} F. That would include 95 KWhrs. for water heating and a loss of 35 KWhrs. for storage. The 130 KWhrs. value is multiplied by four to obtain the 80 gallons of water used in the study. The reason it cannot be multiplied by four, is that after the first individual, much of that water is used for community uses (dishwashing, laundry, etc.). The probable KWhrs. per month needed for 80 gallons of water per day would be around 300 KWhrs. per month and this may be over stated slightly (Lottman 1980). Using the 300 KWhrs. per month estimation makes the annual consumption for heating hot water 3600 KWhrs.

When calculating space heating values for a 1500 square foot home, there is a great deal of variance due to building construction and equipment used to heat with. Assuming a heat loss of about 22 BTUs/square foot (windows, doors, etc.), and an average of 600 heating hours per year, KWhr. per year consumption can range from 2320 KWhr. for a heat pump system, to 5800 KWhr. for a strip heating system. Combining these estimations, makes the range for KWhr./year used for heating water and space between 5920 for the

TABLE 27

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING BEST CASE PRICES: 5% DEMAND GROWTH SCENARIO FOR ELECTRIC

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	(5920 KWhrs.)	(.0243¢/KWhrs.)	=	$107.89
1981	(.75)	(5920 KWhrs.)	(.0260¢/KWhrs.)	=	115.44
1982	(.75)	(5920 KWhrs.)	(.0280¢/KWhrs.)	=	124.32
1983	(.75)	(5920 KWhrs.)	(.0298¢/KWhrs.)	=	132.31
1984	(.75)	(5920 KWhrs.)	(.0320¢/KWhrs.)	=	142.08
1985	(.75)	(5920 KWhrs.)	(.0342¢/KWhrs.)	=	151.85
1986	(.75)	(5920 KWhrs.)	(.0366¢/KWhrs.)	=	162.50
			TOTAL SAVINGS		$936.40
			(7 payback periods)		

The estimated payback period for solar investment is 7 years when substituting solar for 75% of the electricity normally used, using best case price estimations assuming a 5% demand growth.

TABLE 28

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING EXPECTED CASE PRICES:

5% DEMAND GROWTH SCENARIO FOR ELECTRIC

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	(5920 KWhrs.)	(.0253¢/KWhrs.)	=	$112.33
1981	(.75)	(5920 KWhrs.)	(.0276¢/KWhrs.)	=	122.54
1982	(.75)	(5920 KWhrs.)	(.0302¢/KWhrs.)	=	134.09
1983	(.75)	(5920 KWhrs.)	(.0329¢/KWhrs.)	=	146.08
1984	(.75)	(5920 KWhrs.)	(.0360¢/KWhrs.)	=	159.84
1985	(.75)	(5920 KWhrs.)	(.0394¢/KWhrs.)	=	174.94
1986	(.75)	(5920 KWhrs.)	(.0429¢/KWhrs.)	=	190.48
			TOTAL SAVINGS		$1040.29

(6.25 payback periods)

The estimated payback period for solar investment is 6.25 years when substituting solar for 75% of the electricity normally used, using expected case price estimations assuming a 5% demand growth.

TABLE 29

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING WORST CASE PRICES:

5% DEMAND GROWTH SCENARIO FOR ELECTRIC

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	(5920 KWhrs.)	(.0263¢/KWhrs.)	=	$116.77
1981	(.75)	(5920 KWhrs.)	(.0294¢/KWhrs.)	=	130.54
1982	(.75)	(5920 KWhrs.)	(.0330¢/KWhrs.)	=	146.52
1983	(.75)	(5920 KWhrs.)	(.0365¢/KWhrs.)	=	162.06
1984	(.75)	(5920 KWhrs.)	(.0410¢/KWhrs.)	=	182.07
1985	(.75)	(5920 KWhrs.)	(.0453¢/KWhrs.)	=	201.13
			TOTAL SAVINGS		$939.06
			(6 payback periods)		

The estimated payback period for solar investment is 6 years when substituting solar for 75% of the electricity normally used, using worst case price estimations assuming a 5% demand growth.

TABLE 30

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING BEST CASE PRICES:

4% DEMAND GROWTH SCENARIO FOR ELECTRIC

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	(5920 KWhrs.)	(.0242¢/KWhrs.)	=	$107.45
1981	(.75)	(5920 KWhrs.)	(.0258¢/KWhrs.)	=	114.55
1982	(.75)	(5920 KWhrs.)	(.0276¢/KWhrs.)	=	122.544
1983	(.75)	(5920 KWhrs.)	(.0294¢/KWhrs.)	=	130.536
1984	(.75)	(5020 KWhrs.)	(.0314¢/KWhrs.)	=	139.42
1985	(.75)	(5920 KWhrs.)	(.0335¢/KWhrs.)	=	148.74
1986	(.75)	(5920 KWhrs.)	(.0358¢/KWhrs.)	=	158.95
			TOTAL SAVINGS		$922.192
			(7 payback periods)		

The estimated payback period for solar investment is 7 years when substituting solar for 75% of the electricity normally used, using best case price estimations assuming a 4% demand growth.

TABLE 31

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING EXPECTED CASE PRICES:

4% DEMAND GROWTH SCENARIO FOR ELECTRIC

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	(5920 KWhrs.)	(.0252¢/KWhrs.)	=	$111.88
1981	(.75)	(5920 KWhrs.)	(.0274¢/KWhrs.)	=	121.66
1982	(.75)	(5920 KWhrs.)	(.0298¢/KWhrs.)	=	132.31
1983	(.75)	(5920 KWhrs.)	(.0325¢/KWhrs.)	=	144.30
1984	(.75)	(5920 KWhrs.)	(.0354¢/KWhrs.)	=	157.176
1985	(.75)	(5920 KWhrs.)	(.0386¢/KWhrs.)	=	171.384
1986	(.75)	(5920 KWhrs.)	(.0420¢/KWhrs.)	=	186.48
			TOTAL SAVINGS		$1025.19
			(6.25 payback periods)		

The estimated payback period for solar investment is 6.25 years when substituting solar for 75% of the electricity normally used, using expected case price estimations assuming a 4% demand growth.

TABLE 32

PAYBACK PERIOD FOR A RESIDENTIAL SITE USING WORST CASE PRICES: 4% DEMAND GROWTH SCENARIO FOR ELECTRIC

Year	% Substitution	Energy Consumption	Price		Yearly Savings
1980	(.75)	(5920 KWhrs.)	(.0262¢/KWhrs.)	=	$116.328
1981	(.75)	(5920 KWhrs.)	(.0290¢/KWhrs.)	=	128.76
1982	(.75)	(5920 KWhrs.)	(.0323¢/KWhrs.)	=	143.412
1983	(.75)	(5920 KWhrs.)	(.0359¢/KWhrs.)	=	159.396
1984	(.75)	(5920 KWhrs.)	(.0399¢/KWhrs.)	=	177.156
1985	(.75)	(5920 KWhrs.)	(.0444¢/KWhrs.)	=	197.136
			TOTAL SAVINGS		$922.188
			(6 payback periods)		

The estimated payback period for solar investment is 6 years when substituting solar for 75% of the electricity normally used, using worst case price estimations assuming a 4% demand growth.

most efficient and 9400 KWhrs. for the least efficient (Lottman 1980). The most efficient figure will be used. Using the lowest KWhr. estimation, will yield the longest payback period.

The payback periods for substitution of solar for electric are shorter than the payback periods for substitution of solar for petroleum or natural gas. A shorter payback period was to have been expected due to the higher price of electricity per BTU. If the solar system were purchased in 1985, it would be expected that the payback periods would be shorter.

The preferred method for estimating payback periods would be to estimate hot water and space heating needs for each residence. It should be obvious that not every house is 1500 square feet and has four people in it.

The conclusion reached, is that with payback periods ranging from 6 to 12 years in length, solar energy installations are economically attractive today. While the incentive for replacing electricity with solar is greater, the payback periods on the solar system that is substituting for petroleum and natural gas, is less than half the systems expected lifetime and should generate enough funds to replace itself and partially pay for the other 25% energy required.

Industrial and commercial sector payback periods are not considered here. Residential size does not vary as much, nor do the energy consumption patterns differ greatly. In the commercial sector, for example, there is quite a difference in the KWhr. requirements for water heating between a law office and a commercial laundry. The same situation is true for industrial situations. A papermill will use more hot water than an electrical motor factory.

The solution is to do each commercial or industrial application individually in order to determine its needs. The same type of analysis would be used as was applied in the residential sector. Caution should be taken when calculating system cost for industrial applications. Prices for industrial solar systems are approximately one third the cost of residential systems.

CHAPTER V

SUMMARY

Generally, given Florida's expected growth, the price of conventional fuels should increase along with their consumption (which was assumed before the project was started). What is particularly interesting is the pattern of fuel consumption that developed. Given the conditions of the model, Florida is going to become less dependent on oil, but increasingly dependent on natural gas for energy in the residential, commercial and industrial sectors.

The electrical sector patterns differ the most from what would be expected. Oil consumption increases slightly, which was not expected given the recent increases in the price of oil and the shortage of high quality (low pollutant) oil. Natural gas increases as expected considering its high marginal productivity and low cost (natural gas is also more efficient in meeting pollution standards). Also not expected was the relatively slow growth in coal use and the relatively high growth in nuclear electrical generation.

Price was the deciding factor. Nuclear fuel is about one fifth the price of its nearest competitor. However, in this case, the price of the fuel itself is probably understated. The reason for this is that the price of the fuel fails to account for the social costs (if not actual at least the perceived cost of electrical energy generated with nuclear fuel as the consuming public sees it) involved in producing electricity using nuclear fuel. If it were possible to determine and quantify those social costs, it would be possible to include them in the costs of the fuel. It is possible that, at this point in time, an action of this nature would make nuclear fuel more expensive per BTU than oil. While nuclear fuel becomes more expensive, coal would become cheaper due to government support and the availability or longevity of coal supplies. If these "new" prices were included in the model, it is probable that coal consumption would increase at a much faster rate while nuclear generation stayed constant or fell slightly.

While it was shown that solar energy for the home is now economically viable, the impact of this on the results of the model was not considered. Medium to heavy solar innovation would have the same effect as changing the demand growths used in the models. With a greater percentage of the residential sector using solar systems, two results would be obtained. The use of oil and natural gas would change. While oil consumption would still decline, it would decline a little more quickly and natural gas consumption would increase but do so more slowly. Prices of oil and natural gas would tend to be somewhat lower than shown.

There are several suggestions that can be made that would tend to improve the study. New estimates should be made using 1979 price and consumption data as it becomes available. The model should be altered so as to include cross elasticities of demand and demand elasticities of each sector for each fuel should be used rather than the currently used demand for energy. Finally, a more extensive test on the economic viability of solar innovation should be performed using a life cycle cost analysis rather than the simple payback formula used here (although it is expected that the results would be similar).

APPENDIX

TABLE 1

Consumption of Primary Energy in Florida by Sector
1978 Usage in Trillions of BTUs

Type Energy Consumed	Sectors			
	Electric	Residential	Commercial	Industrial
Petroleum				
Liquified Petroleum Gas	0.0	15.0	13.0	2.6
Distillate Fuel Oils				
Kerosene	0.0	3.1	3.1	3.1
Diesel	0.0	0.0	13.3	0.0
Other Distillate Fuels	29.7	4.1	11.2	23.8
Total Distillate Fuel Oils	29.7	7.2	27.6	23.8
Residual Fuel Oils	453.6	0.0	1.3	84.0
Total Petroleum	483.3	22.2	41.9	110.4
Natural Gas	160.8	22.4	28.3	77.5
Coal	163.8	0.0	0.0	7.0
Nuclear	169.9	0.0	0.0	0.0
TOTAL PRIMARY ENERGY	980.1	44.6	70.2	194.9

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

TABLE 2

ELECTRIC SECTOR ENERGY PRICES IN CONSTANT DOLLAR VALUES: 1960-1978

STATE OF FLORIDA

	1960	1965	1970	1971	1972	1973	1974	1975	1976	1977	1978
PETROLEUM											
Other Distillate Fuel Oils (¢/10^6 BTUs)	78.8	75.6	71.3	70.2	67.3	75.4	124.5	138.6	137.8	145.0	135.2
Residual Fuel Oils (¢/10^6 BTUs)	40.0	35.3	26.4	33.1	48.0	46.7	115.4	121.0	105.4	114.1	99.0
NATURAL GAS (¢/10^6 BTUs)	37.9	34.3	30.9	32.1	29.5	32.8	41.2	43.2	47.3	52.2	51.7
COAL (¢/10^6 BTUs)	36.6	30.3	26.3	27.9	33.6	37.5	47.8	62.8	64.3	74.8	78.2
NUCLEAR (¢/10^6 BTUs)	-	-	-	-	-	11.9	10.7	10.3	10.6	9.6	9.2

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

TABLE 3

INDUSTRIAL SECTOR ENERGY PRICES IN CONSTANT DOLLAR VALUES: 1960-1978

STATE OF FLORIDA

	1960	1965	1970	1971	1972	1973	1974	1975	1976	1977	1978
PETROLEUM											
Liquefied Petroleum Gas ($¢/10^6$ BTUs)	112.2	96.3	90.0	82.9	81.0	135.9	171.5	4.9	211.3	217.5	216.8
Distillate Fuel Oils											
Other Distillate Fuel Oils ($¢/10^6$ BTUs)	114.6	107.5	93.6	95.1	93.1	117.0	147.9	158.8	150.9	163.3	157.0
Residual Fuel Oil ($¢/10^6$ BTUs)	47.6	43.1	43.6	58.4	47.5	57.3	122.5	118.1	109.3	123.0	101.4
NATURAL GAS ($¢/10^6$ BTUs)	30.6	36.8	25.4	31.1	36.9	35.2	35.7	41.9	53.7	51.0	61.8
COAL ($¢/10^6$ BTUs)	-	-	-	-	-	-	-	62.8	64.3	74.8	78.2
ELECTRICITY ($¢/10^6$ BTUs)	429.5	372.2	277.2	265.8	304.1	308.3	377.0	436.4	464.1	484.4	494.5

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

TABLE 4

COMMERCIAL SECTOR ENERGY PRICES IN CONSTANT DOLLAR VALUES: 1960-1978

STATE OF FLORIDA

	1960	1965	1970	1971	1972	1973	1974	1975	1976	1977	1978
PETROLEUM											
Liquefied Petroleum Gas (¢/10^6 BTUs)	122.9	106.3	98.2	90.7	88.5	149.5	187.0	209.1	231.5	238.5	237.7
Distillate Fuel Oils											
Kerosene (¢/10^6 BTUs)	120.3	118.3	103.1	103.2	101.0	127.5	190.1	173.2	189.4	201.3	193.9
Diesel (¢/10^6 BTUs)	172.3	164.0	143.2	140.2	139.9	144.1	186.5	229.0	220.3	205.8	192.8
Other Distillate Fuel Oils (¢/10^6 BTUs)	115.3	108.3	94.2	95.7	93.9	118.6	148.9	159.2	152.3	164.8	161.5
Residual Fuel Oil (¢/10^6 BTUs)	48.3	43.8	43.6	58.9	47.5	57.7	123.0	118.5	110.4	123.6	102.1
NATURAL GAS (¢/10^6 BTUs)	157.7	113.1	91.0	98.0	106.3	106.1	119.3	114.5	113.1	124.7	135.8
ELECTRICITY (¢/10^6 BTUs)	925.1	775.3	529.2	507.4	538.0	528.5	615.2	654.5	653.2	678.2	659.3

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

TABLE 5

RESIDENTIAL SECTOR ENERGY PRICES IN CONSTANT DOLLAR VALUES: 1960-1978

STATE OF FLORIDA

	1960	1965	1970	1971	1972	1973	1974	1975	1976	1977	1978
PETROLEUM											
Liquefied Petroleum Gas ($¢/10^6$ BTUs)	122.9	107.4	100.8	92.3	90.3	160.6	193.6	214.3	237.6	244.6	243.6
Distillate Fuel Oils											
Kerosene ($¢/10^6$ BTUs)	131.0	129.3	114.0	113.5	111.7	147.5	209.1	185.2	202.0	214.7	207.1
Other Distillate Fuel Oils ($¢/10^6$ BTUs)	125.3	118.9	104.8	105.2	104.2	137.6	166.9	166.9	167.9	181.5	174.7
NATURAL GAS ($¢/10^6$ BTUs)	322.5	254.8	209.6	202.9	206.5	192.0	181.9	162.6	160.9	189.0	203.8
ELECTRICITY ($¢/10^6$ BTUs)	859.1	713.3	504.0	483.3	491.2	484.4	555.6	618.2	636.0	662.0	644.3

SOURCE: Florida, Department of Energy, "Historical Consumption of Primary Energy in Florida by Sector: 1978" (Tallahassee, FL, 1979).

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